

Time Saving in Medical Imaging Services Integrating Digital Imaging with Six Sigma Concept

Mohamed Ahmed El-sheikh^{*1}, Shamboul M. Adlan² and Alnazier Hamza³

*1. Department of Radiology, National College for Medical and Technical Studies - Email:

elsheikh_mohmed@yahoo.com

2.Faculty of Engineering, Al Mugtaribeen University

3..Biomedical Engineering department, Faculty of Engineering, Sudan University of science and technology

ABSTRACT: The aim of this study was to identify the impact of Six Sigma (6σ) implementation in a radiology setting with radiology information system (RIS), Picture Archiving and Communication System (PACS) facilities compared to traditional department. Six Sigma methodologies were used to analyze the processes, reduce the non-value added steps, improve the processes and calculate the return of investment (ROI). Radiology exam turnaround time and patient's flow, before and after the PACS implementation were analyzed and values were statistically tested to assess workflow and productivity improvements. Statistical elaboration of the collected data showed that the reduction in flow time was 56% and the decrease in report time was 75% when RIS/PACS was used compared to traditional department flow and report turnaround time (RTT). Implementation of six sigma in a digital department with RIS and PACS will improve the quality of performance to an unrecorded level.

المستخلص:

تهدف هذه الدراسة للتعرف على آثار تطبيق منظومة الجودة سيجما ستة (6σ) على تجويد الأداء في مراكز الأشعة التي تشتمل على أجهزة ونظام معلومات وأرشفة رقمية ومقارنة النتائج بمستويات الأداء بمركز الأشعة التقليدية. منظومة نظام سيجما ستة (6σ) تستخدم في تحليل الممارسات العملية وتقليل الخطوات غير المفيدة في العملية لتحسين الممارسة العملية ومن ثم عائد للاستثمار بالمؤسسة. تم قياس وتحليل واحصاء زمن التشخيص وانسياب المرضى قبل وبعد ادخال نظام الأرشفة الرقمية والمعلومات وتطبيق منظومة سيجما ستة (6σ) لتقييم التحسن في زمن تقارير التشخيص وفي زمن انسياب المرضى. بعد المقارنة الاحصائية للمعلومات تبين ان زمن انسياب المرضى قل بمعدل 56% كما ان زمن اعداد التقارير الخاصة بالتشخيص قد قل بمعدل 75%. إن اعتماد منظومة سيجما ستة (6σ) لتحسين الجودة في مراكز الأشعة التي تحتوى على اجهزة ونظام معلومات وأرشفة رقمية يمكن أن يرفع الأداء في هذه المراكز الى مستويات غير مسبوقة.

KEYWORDS: *workflow, image acquisitions, turnaround time*

INTRODUCTION

The complexity of radiology process resulting from the explosion of medical technology made it difficult for radiology personnel to render high quality, defect free, cost-effective radiology service. There is a widening gap between advancing technologies and traditional workflow. Technological advancement seems not enough to fill the quality gap ⁽¹⁾.

The processes surrounding diagnostic imaging services had not kept pace with the imaging acquisition and information communication systems. Today's imaging technologies provide greater speed and superior image quality. Computerized Tomography (CT) scanning of any body system may take few seconds while imaging processes takes 30 minutes or more. If processes are redesigned and standardized, significant reduction in the costs of poor quality could be achieved. Even with the latest equipment installed, many organizations face delays in report-turnaround time and a buildup of patients waiting for appointments.

This situation can lead to a variety of problems for diagnostic imaging facilities or departments, including patient dissatisfaction, delay in diagnosis and treatment, emergency department bottlenecks, increased length of stay, patient dissatisfaction referring physician dissatisfaction, and potential loss of outpatient business revenues ⁽²⁾. Optimizing technology through process improvement is the key to success in improving the level of quality. To optimize performance, technology must not only be leading edge, it also must be appropriately aligned with the people and process steps involved in the delivery of safe and cost-effective patient care. One approach that has proven to be effective involves the implementation of technical strategies such as Six Sigma, along with cultural tools to accelerate change and build acceptance. Process improvement and workflow adjustments using Six Sigma and other tools can have a measurable impact on cost and quality of services ⁽²⁾.

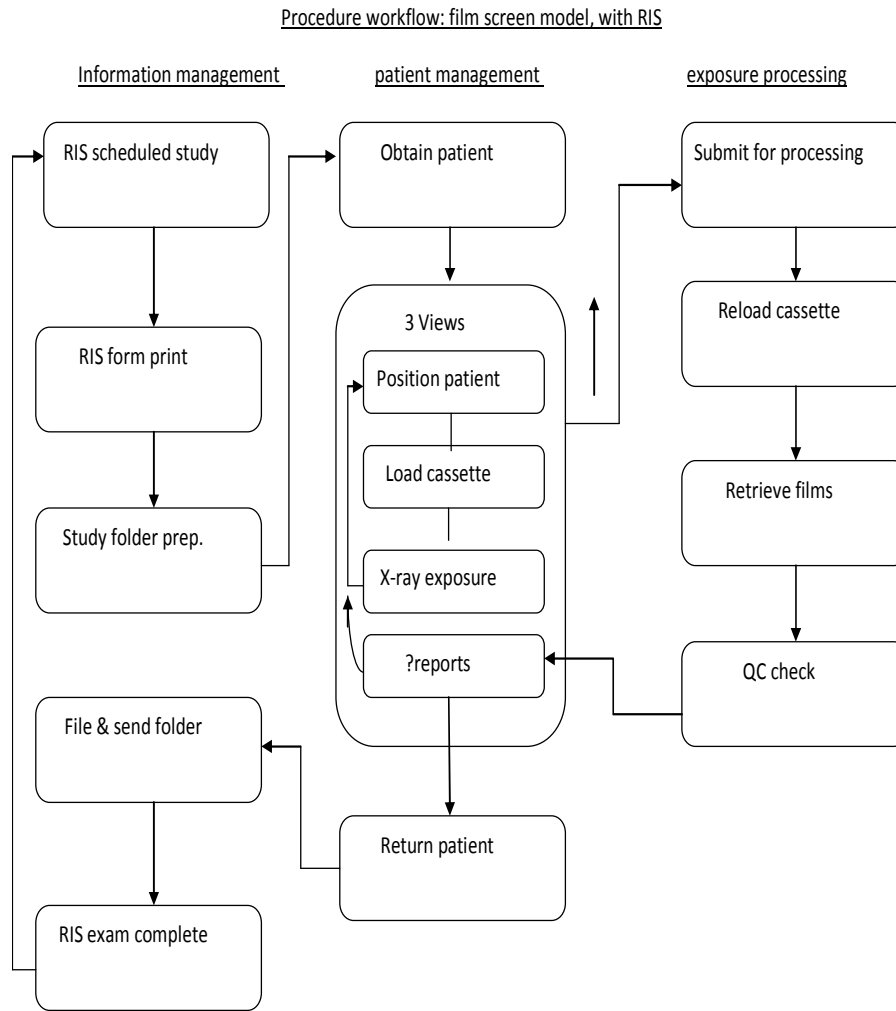


Fig 1: A 12-step procedure workflow model based on film screen film in conjunction with RIS

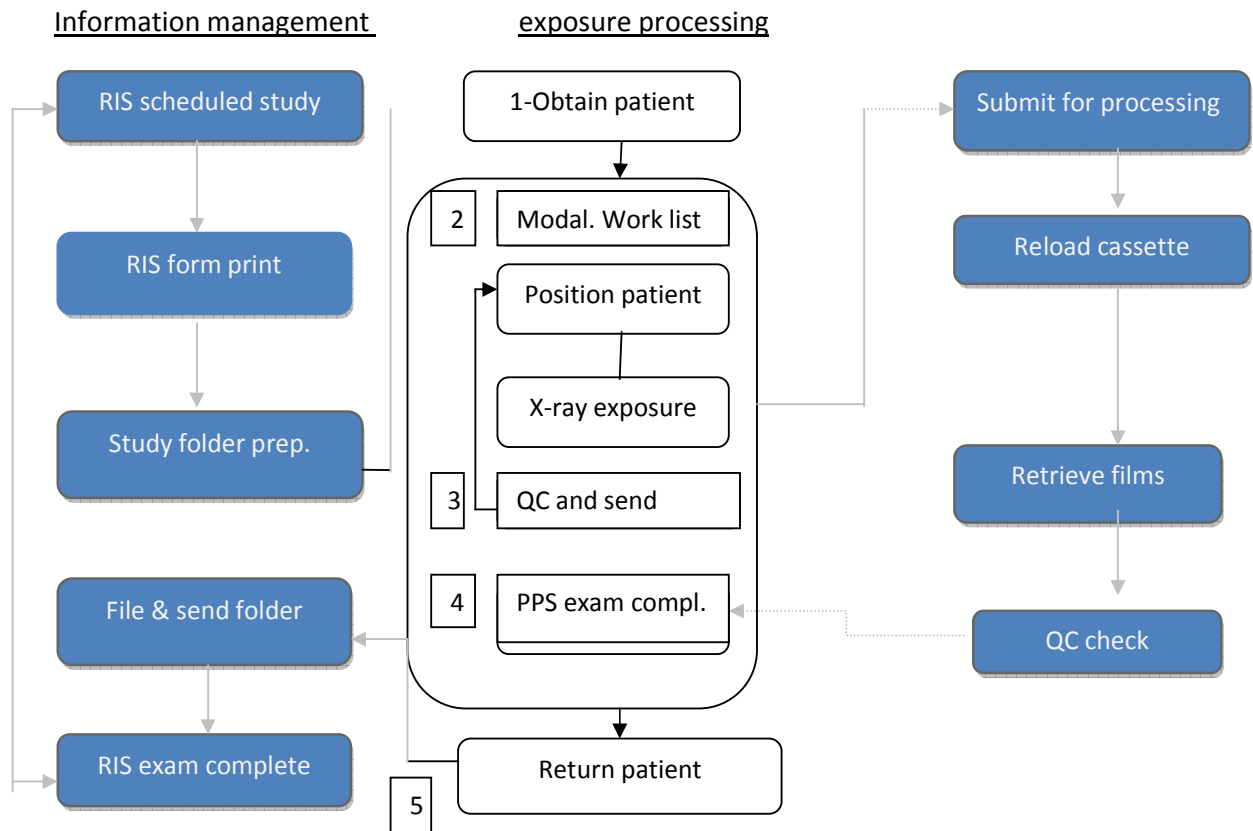


Fig 2: Five steps procedure workflow model based on the use of flat panel digital radiographic system that is fully integrated with RIS –PACS

The integration of six sigma methods with the radiology information management (RIS), digital modality deployment, and picture archiving computerize system PACS deployment would improve efficiency of imaging technology and clinical effectiveness⁽³⁾. The later would be enhanced by acquiring better data from direct or computer radiography, new data from magnetic resonance imaging MRI or Positron Emission Tomography PET, or more data from multi-detector CT⁽⁴⁾.

Quality issues are addressed by optimized adopting a performance-improvement approach that can achieve quality goals, customer satisfaction and return of investment (ROI)⁽⁴⁾.

Achieving optimal efficiency, service quality, customer satisfaction and financial success in diagnostic imaging requires more than the installation of superior equipment and information technologies⁽²⁾. It also entails adopting a performance-improvement approach that

incorporates both a technical and cultural strategy to realize significant, long-term results⁽³⁾.

The study hypothesize that six sigma methodologies could be used in combination with digital transformation RIS/ PACS technology to improve the performance of the diagnostic radiology department to six sigma level of quality.

Six Sigma Theoretical Background

Six-Sigma is a data-driven quality measurement that strives for a near perfection of any process. According to Thomas Pyzdek, who acknowledged as six sigma consultant and author, six sigma can be summarized as, "Six Sigma focuses on improving quality (i.e., reduce waste) by helping organizations produce products and services better, faster and cheaper⁽⁴⁾. Six-Sigma focuses on defect prevention, cycle time reduction, and cost savings. Unlike mindless cost-cutting programs which reduce value and quality, Six Sigma identifies and eliminates costs which provide no value to customers, waste costs⁽⁴⁾.

Six-Sigma has the following methodologies⁽⁵⁾:

- 1.DMAIC: Define, Measure, Analyze, Improve and Control
- 2.DMADV: Define, Measure, Analyze, Design and Verify
3. DFSS: Design for Six Sigma by IDOV- Identify, design, optimize and validate.
- 4.BPMS: Business Process

Management Systems, nine step process.

Mathematical Background

To understand the concept of Six-Sigma one must understand the concept of normal curve.

Normal Distribution Curve

The normal distribution curve is a symmetrical bell shaped graph representing the distribution of a data set. The bell-shaped curve results when a normal distribution is represented graphically by plotting the distribution $f(x)$ against x . The curve is symmetrical about the mean value.

Variance and standard deviation are measures used to express the degree of concentration of data around the center. Variance is expressed by Sigma squared:

$$\sigma^2 = \left(\frac{1}{N}\right) \sum_{i=1}^N (x_i - \mu)^2 \quad (1)$$

The standard deviation, or Sigma, is equal to the square root of the variation. Therefore, one Sigma is simply equal to one standard deviation⁽⁵⁾.

Process Thinking

In the Six Sigma quality methodology, process performance is reported to the organization as a sigma level. The higher the sigma level, the better the process is performing. Another way to report process capability and process performance is through the statistical measurements of Cp, Cpk, Cpk is an index (a simple number) which measures how close a process is running to its specification limits, relative to the natural variability of the process.

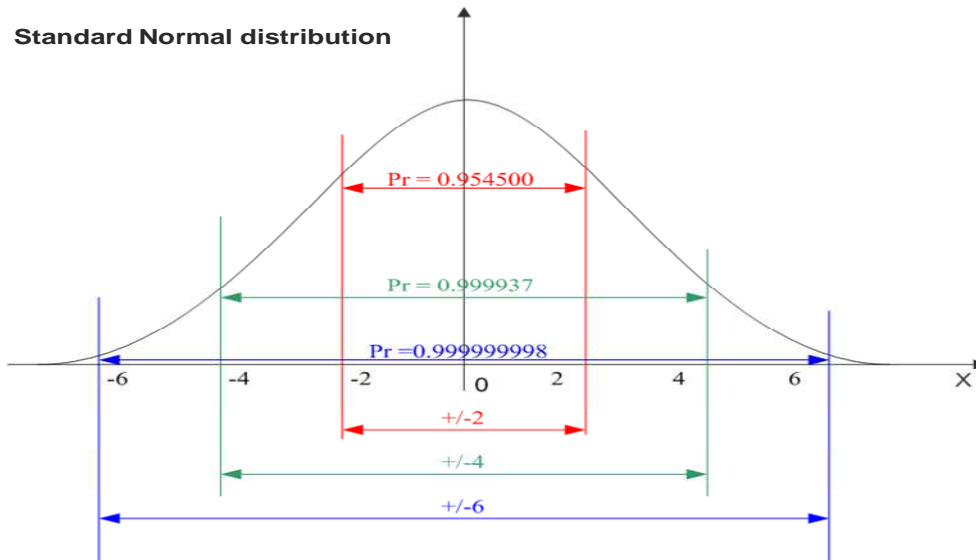


Fig 3: The standard normal distribution

Process Drift

While a defect rate of two parts per billion would be an incredible achievement, such a result is not necessarily attainable. This would only be possible under circumstances when there is no shift in the mean value from batch to batch (a perfectly

centered process). These variations can cause a shift in the mean toward the upper or lower specification limit. This normal process drift is established as plus or minus 1.5 Sigma. Figure (4) below is a graphic depiction of this process.

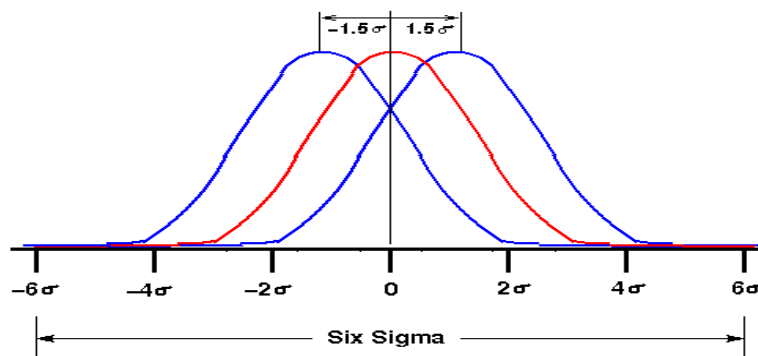


Fig 4: Illustration of process drift of 1.5 sigma

Capability Indices

A capability or performance index (Cp) is a numeric ratio that is very useful in comparing the inherent quality of different product characteristics. This is possible because the calculated index is a dimensionless measurement scale. The index consists of the ratio the distribution width and the engineering specification width. It measures the potential or intrinsic capability of the production process^(4,5).

Cp is given by the formula:

$$C_p = \frac{USL - LSL}{6\sigma} \quad (2)$$

where : USL is the upper specification limit and LSL is the lower specification limit for the product or process. A capability index of 1.0 means that a process is running at 3 sigma quality level. This indicates a stable process and is the minimum acceptable by industry. A capability index of 2.0 corresponds to a six sigma level of quality⁽⁶⁾.

An additional capability index that seeks to account for the +/- 1.5 sigma process drift is the Cpk index. It is defined as:

$$C_{pk} = \min \left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma} \right)$$

Six Sigma Calculation

The calculation of Six Sigma level is based on the number of defects per million opportunities (DPMO). In order to calculate the DPMO three distinct pieces of information are required:

- a) The number of units produced
- b) The number of defects opportunity per unit
- c) The number of defects

The actual formula :

$$DPMO = \frac{(NUMBER\ OF\ DEFECTS \times 1,000,000)}{((NUMBER\ OF\ DEFECTS\ PER\ UNIT) \times NUMBER\ OF\ UNITS)} \quad (4)$$

For any business process six sigma methodology offers following benefits⁽⁴⁾.

1. Fewer defects
2. High customer focus – Voice of customer (VOC)
3. Lower costs – General Electric Company GE, Motorola has saved billions of dollars
4. High Employee focus – Voice of employee (VOE)
5. Data driven better decision making
6. Effective management vision

Methodology

In this study, six-Sigma methodologies optimize the whole process flow and improve report turn time RTT. Duration of the steps of the whole radiological process (Process Time) was measured. Process Time is defined as the interval running from patient arrival at the Front Office of the Radiology Department (for registration) to report delivery. The times were acquired to compare a traditional radiological workflow with one based on a RIS/PACS system. The analysis was by comparing management methodologies and computing the average time of each step, after the definition of the main steps for both working flows. The total mean time was then computed.

RESULTS

Define phase

Project Title: Report Turnaround Time (RTT)

Business case: The report turnaround time is defined as the time between completion of the activity and the time when the final report is made available to the physician or administrator. Report turnaround time has long been the annoyance of the radiologist's existence. It is one of the most critical factors in assessing clinicians' satisfaction with imaging services. In Madinat Zayed radiology department reporting time of 72 hours is the standard in most cases that includes emergency ER and Intensive care unit cases ICU. Some of the clinician expresses their dissatisfaction of the long RTT, particularly Emergency Departement (ER) , Intensive Care Unit (ICU) clinicians.

Problem /opportunity statement

A number of factors can cause delays in the interpretation/reporting process,

and these are largely the result of insufficient or poor quality data. Poor image quality, incomplete examinations, lack of availability of historical examinations and reports, and limited access to relevant clinical data can all result in radiologist interpretation delays. 72 hours RTT was reported in 85% of ER, ICU CT cases. This may increase length of stay of patient in ICU, which means additional cost of care.

Goal statement: Reduce RTT by 50% for CT cases.

Project scope: A project on report turnaround times and communication issues would include collection of baseline data for the individual radiologist. A plan to improve the turnaround time for CT scans cases. Data is collected for a month duration in 2006 and at the same time and duration in 2007 and 2008, respectively.

Figure (5) shows a process time in a traditional radiology dept 18 hours, report turns time 72 hours and scheduling time of 3 days.

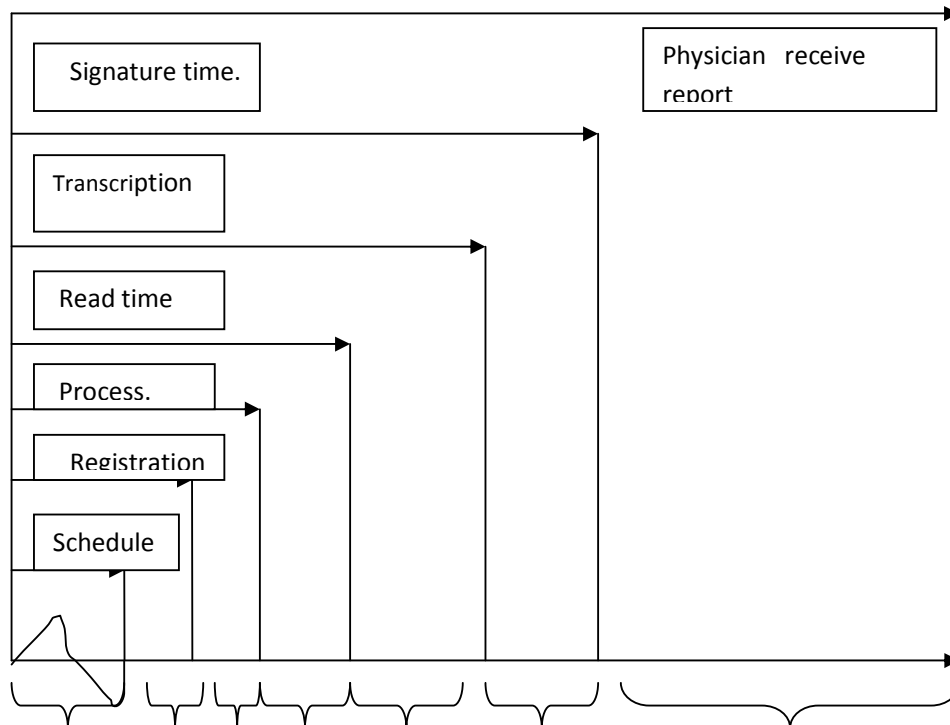


Fig. 5: A process time in a traditional radiology dept 18 hours ,Report turns time 72 hours and Scheduling time of 3days

Measure: a special template was used for estimating the time it takes for the radiology report to reach the requesting physicians desk or patient file which was found to be 72 hours, starting from the end of imaging process to the time the clinician receive the report.

Analysis: Statistical analysis of the process data showed that four key steps were adding a considerable amount of time to the turnaround time: a) Technologist data entry into the radiology information system (RIS).

Transcription

- a) Report signature
- b) Report delivery

Improvement in process flow

Process flow time steps are reduced due to the digital format of patient registration and the retrieval of patient data from the HIS and by omitting the non value added steps of the process . The reduction was 89% as shown in table (1) below. Figure (6) shows the record turnaround process flow map.

Table (1) Time percentage reduction of a digital process compared to a traditional one
 ST = standard case: workflows without mistakes and/or problems are excluded

Process	Traditional department	Digital department & six sigma	Reduction %
	ST	ST	%
Patient registration time	25 min	5 min	80
Execution time	15 min	10 min	33
Reporting time	240min	20 min	92
Typing time	25 min	5 min	80
Correction/Signature time	15 min	00	100
Report delivery time	90 min	5 min	94
Total time	410 min	45 min	89

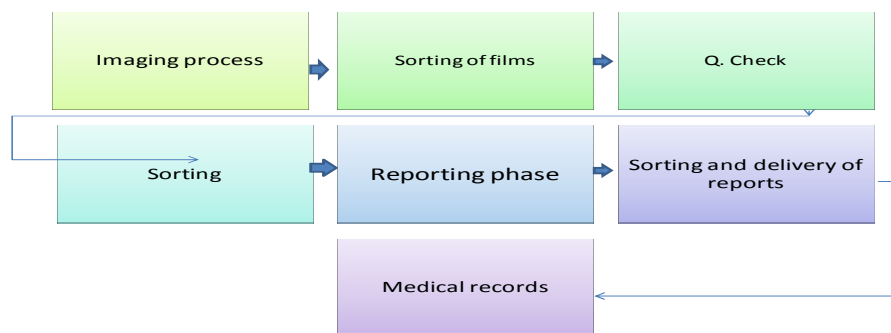


Fig.6: Report Turnaround process flow map

Improvements: The introduction of a PACS improve dramatically the reporting time . The process is reduced to imaging process, film reconstruction and reporting process. Initial reporting of ICU and emergency cases was suggested.

Normal reporting takes average time of 18 to 12 hours.

Consideration of human errors is always there. Figure (7) shows the post PACS process flow improvements.



Fig 7: the Post PACS process flow

Control

To help sustain the progress, a report was developed to highlight missing RIS data. With the report, defects can

be identified quickly and fixed in a timely manner. A 90% reduction was achieved when the traditional reporting was replaced by electronic reporting through a PACS.

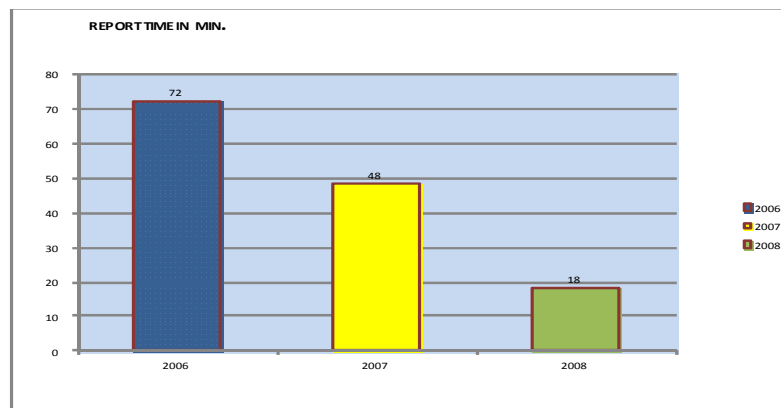


Fig. 8: the reduction in RTT of the traditional flow with that of digital department flow

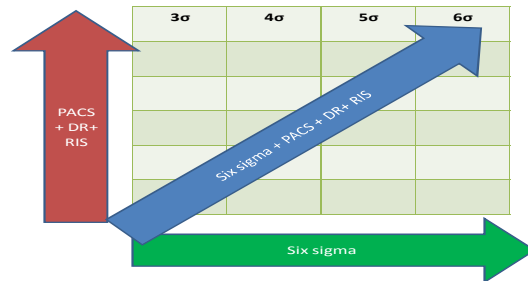


Fig.9: Impact of combining Six Sigma model
with PACS RIS and DR system

DISCUSSION

Transition from analogue to digital department was aimed to improve the quality and efficiency of the radiology services through improving the processes, the quality of imaging acquisition, producing timely and accurate reports, while simultaneously increases the throughput and financial benefits of the radiology services.

In the past century the radiologic operation was based on the film screen recording the development of film on chemical either manually or by using automatic processors which was later developed to daylight system. The technologist was able to process x-ray film without going into a darkroom in only 90 seconds⁽²⁾.

Automation of the imaging processes was not the end goal, further innovations on digitization of whole department in the last 15 years lead to dramatic changes in imaging acquisition, image recording, patient flow and process time.

The availability of a flat –panel digital detectors radiographic system that do not require cassette handling has made further enhancement of the workflow possible, in a study by Flynn (2003) . it was shown that due to advances in digital radiography steps in the traditional workflow were reduced shortened or even eliminated⁽⁷⁾. With this type of systems the technologist never leaves the patient alone which means better patient care. The productivity in terms of more patient throughput is increased

A considerable impact is created on management of the workflow process. In some departments it was demonstrated that, when integrating information systems and digital units the process was reduced from 59 major steps to only 9 for an inpatient chest radiograph⁽⁷⁾.

Another study showed a time saving from 8% to 25% in report turnaround. In a study about chest radiographs, it was demonstrated that the median

time from transcription to final signature decreased from 10 to 5 days with the introduction of electronic signature⁽⁸⁾.

Image acquisitions, and repeat of lost examinations, are the areas most affected by the transition to filmless imaging in the execution of radiographic examinations. Reporting time is also affected by the introduction of speech recognition and electronic signature, eliminating interactions between the radiologist and the secretary. It was proved that time of report generation (Report Turnaround Time), measured from the end of the examination up to the time when film and report are available for delivery, is largely reduced. Speech recognition influences time between report dictation and report transcription. In a particular study, the mean turnaround time declined from 87.8 to 32.3 h and the 24-h report availability is 71.1 %⁽⁹⁾.

In the RSNA study procedure workflow model for filmless CR system with integrated RIS/PACS involves seven steps compared with 12 steps for a screen film model⁽³⁾.

Reductions in film printing and file room clerks saved \$1,001,452 annually, while the number of radiology studies increased from 317,000 the year pre-PACS to 340,000 the year after.

When implemented efficiently, digital radiology imaging systems also can provide system-wide cost savings and have the potential to improve care for patients. The study demonstrates that new digital technology, when implemented with attention to the clinical user, can improve satisfaction,

efficiency, cost and clinical behaviors^(10,11).

Between the half of 2004 and the respective period in 2003, Reggio Emilia hospital overall Radiology Department productivity increased by 12%, TAT improved by more than 60%⁽¹²⁾.

In a study published in the American journal of radiology by Halsted (2008), the study supported the idea that software tools that coordinate decentralized workflow and dynamically balance workloads can increase the efficiency and efficacy of radiologists. Operational benefits, such as reduced reading times, improvements in the timeliness of care (both actual and as perceived by patients), and reduced interruptions to radiologists, further reinforce the benefits of such a system. Secondary benefits, such as documenting communication about a case and facilitating review of results, can also promote more timely and effective care⁽¹³⁾.

CONCLUSIONS

New technologies advancement doesn't necessarily improve radiology services unless integrated by an appropriate quality concept such as six sigma. Six Sigma is one of the rigorous quality models, which has reported successes in improving process quality, patient work flow and consequently return of investment. Digitizing imaging and implementation of PACS and RIS will increase the chances that radiology services achieves six sigma level of quality by improving processes timing, increases benefits, increasing customer satisfaction, eliminating defect in

images quality to less than 3.4 defect per million opportunity (DPMO).

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